

National Defense Industrial Association
Manufacturing Division

**The Imperative Military Need for Portable Power
and the Critical Problems With Power Today**



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Preface

The modern U.S. warfighter relies upon technology to take the advantage in both strategic and tactical situations, through advanced weapons, vehicles, communications, sensors, and displays. The price for this technology is power and the requirement for batteries and other sources of power is critical and ever increasing. Today power sources are a significant portion of the overall weight carried by a soldier and more often than not these power sources are not compatible with each other. Furthermore, portable power sources form a large part of the DoD's logistics trail due to the multiple varieties of disposable, single-use batteries.

However, there are pacing advances in power source technology and production, resulting in possibilities for significant gains in performance and reduction in weight. The NDIA Military Power Sources Committee has collaborated on a DoD-sponsored Power Sources Technology Roadmap, which provides a path to future power sources for defense applications. This white paper summarizes the DoD's "power gap" requirements, the roadmap results, and the conclusions regarding future availability of power sources.

NDIA's Manufacturing Division prepared this document to acquaint leaders and decision makers with the importance of power to the warfighter and to direct them to a comprehensive, fact-based R&D roadmap. This document provides recommendations as to what is required to ensure the availability of portable power in safe and reliable packages, with an industrial base that can surge to match operational needs. Today's warfighter has become more and more reliant on technology and the ever increasing requirements to power that technology; the time to act on these requirements is now. Additional copies of the white paper can be found at:

http://publish.ndia.org/Divisions/Divisions/Manufacturing/Documents/White%20Papers%202011/NDIA_Man_Div_White_Paper_3_111v2.pdf

Sincerely,



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CONTENTS

<u>PREFACE</u>	ii
<u>CONTENTS</u>	iii
<u>OVERVIEW</u>	5
<u>2009 DOD POWER SOURCES TECHNOLOGY ROADMAP</u>	7
<u>CONCLUSIONS</u>	10
<u>SUMMARY</u>	11
<u>CONTRIBUTORS:</u>	12

OVERVIEW

The ability of the United States military to decisively defeat its enemies is greatly due to the ability of its warfighters to see first, react first and strike first. This dominance is due to the widespread use of electronic systems, from Night Vision goggles and personal computers to unmanned vehicles and smart munitions. Of course all of these electronic systems require some form of electric power, and in every case that electric power source must be small, light, available and energetic -- in other words a battery.

Since World War II, the military has had a growing need for portable power (i.e. batteries) and this need has increased dramatically in recent years with the proliferation of electronic systems. Initially the ability to meet our military's energy needs for portable electronic systems was your basic standard carbon zinc "D cell" battery, the same technology that powered your flashlight. An example is the "walkie-talkie" pictured below, which was powered by 4 of these batteries and the only portable electronic device used by a soldier. Today – the reliance on electronics systems as a force multiplier, and hence the batteries they use, is much greater. As illustrated in the picture below, the average soldier has batteries in (1) his gun sight, (2) his squad radio, (3) his global positioning system unit, (4) his Night Vision goggles and even (5) his watch.



WW II "walkie talkie"



Soldier of today

For many years, advances in military electronics and battery improvement were at the same pace. Beginning in the early 1990s the power requirements of the newest generation of military electronics began to rapidly outpace the ability of the batteries to provide the required amount of energy. The reason is, that unlike Moore's Law (which says that computing power doubles roughly every two years), improvements in *energy* storage and *power* generation, especially batteries, is more *evolutionary* than *revolutionary*. A notional depiction of this is in Figure 1, which illustrates that unless there are actions taken to develop advanced technologies, the shortfall between the energy required by advanced weapon systems and that which will be available could result in what is termed a "Power Gap", which means the full functionality of the system may be compromised by the lack of available power.

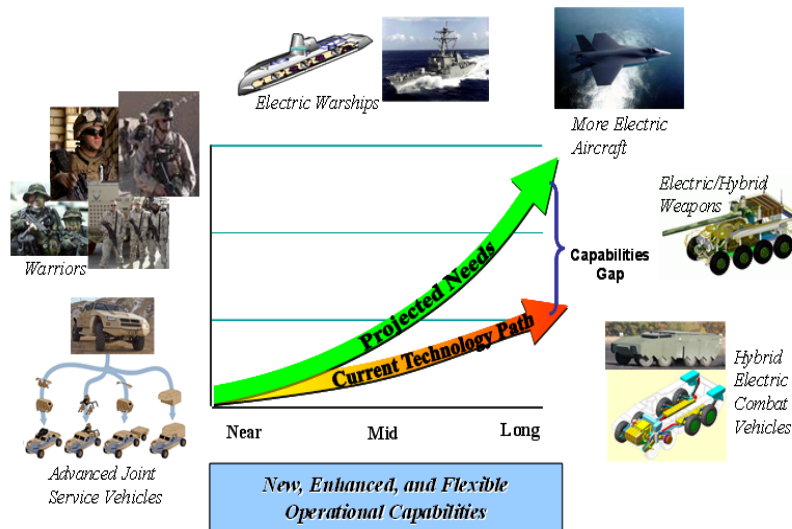


Figure 1.

Notional representation of the potential “power gap”

Further complicating this issue is the lack of research and development investments being made in military battery technologies. In many, but not all, weapon systems the military is able to leverage advances made in the commercial market, such as utilizing the standard alkaline “AA” battery or one of the lithium ion technologies. But our ability to continue to use commercial technologies may be coming to an end. This is due to the combination of the military’s equipment having to operate under extreme environmental conditions (desert sun and arctic cold) along with the need to package greater energies into smaller volumes than what is required for commercial electronics.

The need for small, lightweight, state of the art energy sources is well documented. In 1997, a study titled “Energy-Efficient Technologies for the Dismounted Soldier” by the National Research Council concluded that “The power requirements of the Land Warrior system will limit the effectiveness of the dismounted soldiers on the digitized battlefield”. More recently, the 2007 DOD Research & Engineering (DOD R&E) Strategic Plan highlighted Energy & Power Technologies as an important Capabilities and Enabling Technology Investment Area. Likewise, the National Defense Authorization Bill for Fiscal Year 2009 identified the following two key themes for attention in the Energy & Power arena:

- **Readiness and Management Support – Energy Considerations in Weapon Systems Development:** Directs DOD to develop a plan that would require program managers to incorporate energy efficiency requirements into the key performance parameters in the acquisition of military weapon systems and provide Congress an annual report on the Department’s plans and accomplishments.

- **Emerging Threats and Capabilities – Electronics and Power Technologies for Military Systems & Operations:** Enhances the Department's ability to procure and use critical power and electronics technologies, by requiring the development of a joint government-industry battery technology roadmap to ensure that a healthy and innovative defense industrial base for batteries exists in the United States, to support requirements in military vehicles, computers, and other equipment.

There is a growing trend to develop a weapon system's capabilities with little attention given to the power source, especially if it is a battery. The ability to provide unlimited battery power seems to be taken for granted in the military just as it is in the commercial world. As the requirements for battery power grow, without the corresponding development of new technologies to meet the rising demand the result will be increased numbers (and weight) of batteries to be supplied and carried, along with huge increases in the costs to procure and provide these batteries. To ensure the energy needs of those critical weapon systems required to ensure dominance on the battlefield are met will require a wide variety of energy sources in multiple configurations. The ability to develop these devices in an efficient manner requires a systemic approach to identifying the gaps in technology and a roadmap for prioritizing the limited resources that will be available in the future.

2009 DOD POWER SOURCES TECHNOLOGY ROADMAP

In an attempt to identify these performance gaps and as a tool for allocating resources, the Joint Defense Manufacturing Technology Panel (working under the cognizance of the (then) Director of Defense Research and Engineering) sponsored the development of a DOD Power Sources Technology Roadmap. A copy of the Roadmap can be obtained by contacting the project leader, Marc Gietter, at marc.d.gietter@us.army.mil. The goal of the Roadmap is to provide a concise, coherent, and actionable pathway, the execution of which would help ensure that state of the art power sources are available to the Nation now and in the future.

The Roadmap focuses on electric-chemical power sources (batteries and fuel cells) for use in munitions, man-portable, vehicle, and aviation applications. The Roadmap then breaks these power sources into four broad technology sectors: (1) non-rechargeable batteries, (2) rechargeable batteries, (3) thermal/reserve batteries and (4) 1 watt to 1 kilowatt fuel cells. Each of the technologies is then further broken down by chemistries (for batteries) and fuel sources (for fuel cells) that are now or are projected to be in common use by the warfighter.

The first step in the development of the roadmap was to match each chemistry/fuel source against a common set of performance requirements (based on the needs of the warfighter). The goal for this step was to determine if the chemistry/fuel source is currently capable of meeting the requirement now and five and ten years in the future. Where a gap was identified, a corrective action was proposed along with a rough order of magnitude of the required investment.

Figures 2- 5 portray the various battery and fuel cell technologies projected to be in the DOD inventory over the next ten years. For some of these technologies, no strategic DOD investment is recommended. This is due to either (1) the technology is being phased out (i.e. nickel cadmium by rechargeable lithium), or (2) it is considered a “use as is” technology (i.e., alkaline or lithium thionyl chloride batteries).

For those technologies where investment is recommended, the figures below indicate the current maturity of the technology and the time required (assuming all of the required resources are made available) for it to become mature. Red indicates the technology meets few, if any of the requirements. Yellow indicates the technology meets some of the requirements and green means the majority of the requirements are being met.

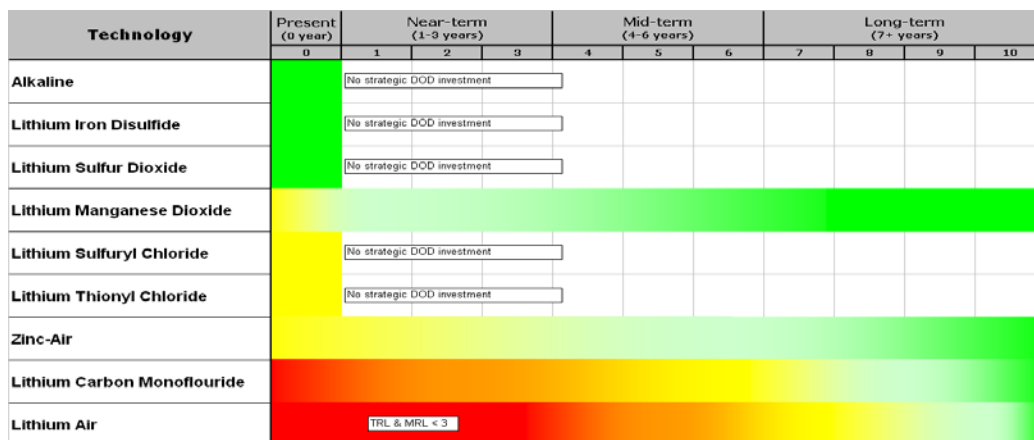


Figure 2.

“Evolution” of non-rechargeable batteries (used in systems such as tactical communications, remote sensors, GPS)

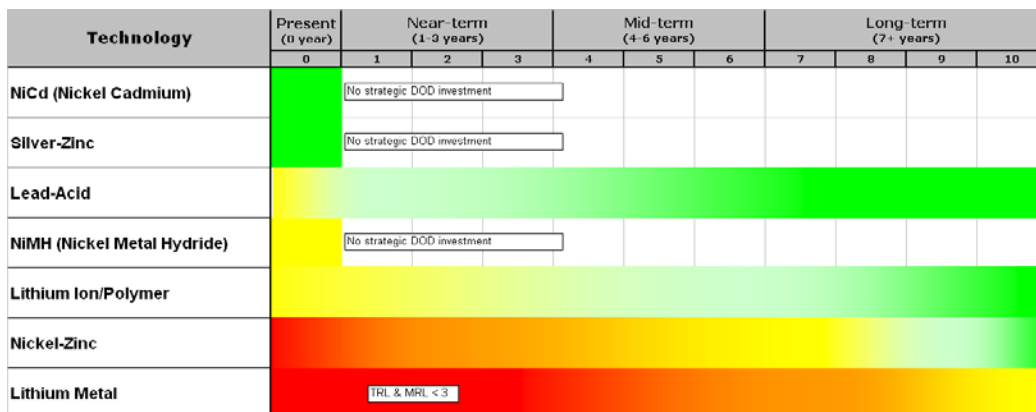


Figure 3.

“Evolution” of rechargeable batteries (used in tactical communications, aviation and vehicle platforms, unmanned vehicles and robots)

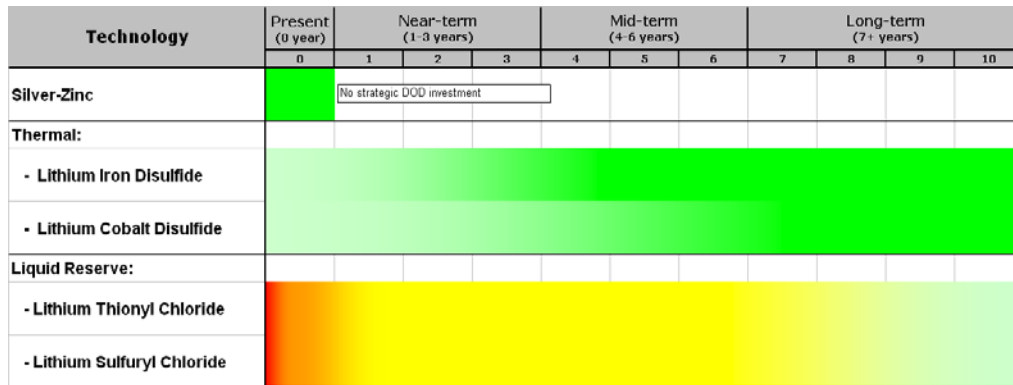


Figure 4.

“Evolution” of reserve batteries (used in various munitions and missiles)

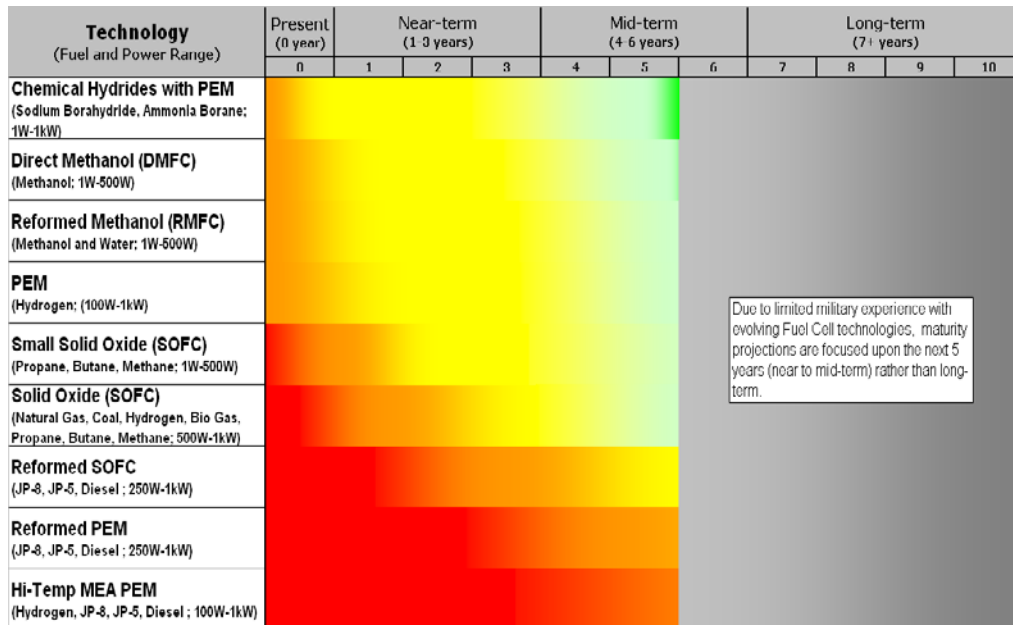


Figure 5.

“Evolution” of 1W – 1kW fuel cells (used as a tactical power source in remote locations)

As a technology matures, it moves from “red” to “green” and the nature of the investment changes. For example, the non-rechargeable lithium air battery is currently “red” meaning that the investment needs to be in basic research and development in materials and compounds (6.0 to 6.1). As it progresses through the “yellow”(6.2 – 6.4) the investments would be aimed at refining the technology and making it producible. For each technology the effort required to bring it to maturity varies, and the Roadmap captures these investments and actions.

CONCLUSIONS ABOUT WHAT IS NECESSARY TO ENSURE THE AVAILABILITY OF POWER SOURCES FOR THE WARFIGHTER

Several overarching conclusions are obvious. These apply to all technologies covered in the Roadmap and are considered essential for implementing a strategic approach to resolving the challenges that face the Warfighter. These conclusions are:

- Adequate, and reliable power and energy are essential to the Warfighter. The ability of the warfighter to see first, react first and strike first is predicated on having sufficient portable power available to operate critical weapon systems. Failure to provide these power sources will result in degraded mission capability.
- Warfighter requirements for power and energy will continue to increase faster than capabilities of current power and energy technologies. The inability to provide state of the art power sources to meet the increasing needs of the end item will result in either less capability in the system (as measured in run times or functionality) or more batteries/fuel (for fuel cells) to be carried into combat.
- Warfighters will need to carry multiple batteries to complete a mission, which has its own consequences. At the individual soldier level, the impact is best exemplified by the Capability Development Document (CDD) For the Squad Multipurpose Equipment Transport (S-MET): "The issue of excessive Soldier Load has been recognized at the highest levels of Army leadership." On March 11, 2009 the House Subcommittee on Defense held a hearing on Soldier Equipment, Ergonomics, and Injuries, chaired by Congresswoman Kaptur who, quoting General Chiarelli, the Vice Chief of Staff of the Army, stated "the Army has over 20,000 Soldiers in a non-deployable status, many of them due to injuries received by carrying a very heavy combat load over rugged terrain for an extended period." The loads that our Soldiers and Marines carry over extended distances, over rough terrain, and often at high altitudes frequently exceed 100 pounds. Body armor alone can weigh 30 pounds. The personal weapon, ammunition, water, possibly a radio, spare batteries, all add to the load that must be carried. It also increases the pressure on the logistic tail, meaning more vehicles and soldiers must be dedicated, and put at risk, to move energy forward to the combat zone.
- Increased power and energy capabilities through technology improvements alone will not meet future requirements. There is a need to focus on a holistic approach that includes not only better power generating technologies, but the ability for the weapon system to use the power generated in the most efficient manner possible.
- Strategic investments are required in both the materials sciences and the manufacturing capabilities of military-unique technologies, especially for those technologies that have no commercial equivalent (munitions) or for requirements that exceed those for the consumer (high and low temperature, storage and power drain).

The Knowledge Base for military-unique power systems is declining and knowledge sharing needs improvement. This is at an inopportune time with the increasing reliance on portable power sources and a DOD-wide emphasis on reducing the consumption of fossil fuels, ergo increasing the use of rechargeable batteries and fuel cells. Even if there is an increased focus on these technologies in the commercial marketplace, expertise needs to be developed within DoD to ensure commercial advances will be leveraged into military applications.

SUMMARY

The ability of our Nation's warfighters to maintain dominance on the battlefield is dependent on electronics, which are in turn dependent on portable power sources. The ability of those power sources to provide power is being outpaced by the power consumption of the end item applications with potentially disastrous consequences. It is therefore imperative that actions be taken to close the gap between the power consumption of weapon systems and the ability to provide this power.

There are some critical overarching recommendations aimed at assuring the availability and affordability of state of the art power sources for our military warfighters:

- Increased funding must be allocated to basic research as it applies to power generating technologies, specifically for those technologies that are unique, or suitable for adaption for military unique platforms. This is required to increase our understanding and utilization of materials science as it relates to promising technologies. Specifically, investments need to be made in the research and development related to electrodes, electrolytes, separator materials, thermal management, materials processes, miniaturized components, and safety. This effort should leverage investments being made by the Government in electric vehicles and other alternative energy storage devices.
- Increased emphasis and resources must be placed on the process for transitioning technologies from the advanced development of promising technologies to full scale production. Specifically, investments should be made in manufacturing processes and techniques to enhance production and automation of military unique technologies. Investing early in the development cycle will decrease life cycle costs (of which power generation is a huge driver) and promote the use of these technologies in the commercial market.
- In order to accomplish the foregoing, a curriculum should be created within the Science, Technology, Engineering and Math (STEM) programs that focuses on electrochemistry and a 'power sources' career path established within industry and DoD.
- The end item development community must continue to aggressively pursue power management techniques. Further, developers of end item applications must work closely with the power generation community to ensure power generation requirements can be met and if not, that the energy available is used in the most efficient manner possible.

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